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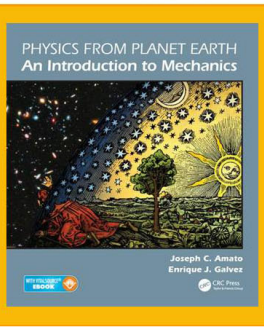

Comment on "Generalized power versus efficiency characteristics of heat engines: The thermoelectric generator as an instructive illustration," by J. M. Gordon [Am. J. Phys. 59, 551–555 (1991)]

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In a recent article[1] in this Journal, Gordon considered the characteristics of a thermoelectric generator that converts heat directly into dc electricity. The analytic results for the case of reversible heat exchange are correct, but the analytic results for the case of finite-rate heat exchange are incorrect. It is shown easily that when the thermal conductance K_H between the hot reservoir and thermoelectric generator is equal to zero, the net rate of heat input Q_H should be equal to zero. Similarly, when the thermal conductance K_C between the cold reservoir and thermoelectric generator is equal to zero, the net rate of heat rejection Q_C should be equal to zero. On the other hand, when $K_H \neq K_C$, the Joule heat I^2R produced inside the device, in general, flows unequally to the hot and the cold junctions. Therefore, when heat exchange is modeled as irreversible and governed by Newtonian (linear) heat conduction, the net rates of heat input and heat rejection of a thermoelectric generator should be

$$Q_H = K_H(T_H - T_1) = IT_1\alpha - bI^2R + K(T_1 - T_2),$$

and

$$Q_C = K_C(T_2 - T_C) = IT_2\alpha + (1-b)I^2R + K(T_1 - T_2),$$

respectively, where I, α, R, K, T_1, T_2, T_H, and T_C have the same meaning as in Ref. 1, and b may be supposed to be equal to $K_H(K_C+2K)/[2(K_HK_C+K_HK+K_CK)]$. It is thus obvious that Eqs. (14)–(17) and some of the following results in Ref. 1 are incorrect.

From the equations mentioned above, we can obtain the power output of a thermoelectric generator

$$P = Q_H - Q_C = I\,\frac{\alpha K_H K_C (T_H - T_C) - [\alpha^2(K_H T_H + K_C T_C) + RK(K_H + K_C) + RK_H K_C]I + \alpha R[bK_H - (1-b)K_C]I^2}{K(K_H + K_C) + (K_H + \alpha I)(K_C - \alpha I)}.$$

Obviously, the characteristics of a thermoelectric generator may be derived from this equation and some significant conclusions can be obtained.

[1] J. M. Gordon, "Generalized power versus efficiency characteristics of heat engines: The thermoelectric generator as an instructive illustration," Am. J. Phys. **59**, 551–555 (1991).

WHEN I HEARD THE LEARN'D ASTRONOMER

When I heard the learn'd astronomer,
When the proofs, the figures, were ranged in columns before me,
When I was shown the charts and diagrams, to add, divide, and measure them,
When I sitting heard the astronomer where he lectured with much applause in the lecture-room,
How soon unaccountable I became tired and sick,
Till rising and gliding out I wander'd off by myself,
In the mystical moist night-air, and from time to time,
Look'd up in perfect silence at the stars.

Walt Whitman, 1865.

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